Available online at www.sciencedirect.com

ScienceDirect

Renewable and Sustainable Energy Reviews 13 (2009) 863–870

RENEWABLE & SUSTAINABLE ENERGY REVIEWS

www.elsevier.com/locate/rser

External cost of electricity generation in Baltic States

Dalia Streimikiene [a,*], Inge Roos [b], Janis Rekis [c]

[a] Lithuanian Energy Institute, Breslaujos 3, LT-44403 Kaunas, Lithuania
[b] Tallinn University of Technology, Department of Thermal Engineering, Kopli 116, 11712 Tallinn, Estonia
[c] Investment and Development Agency of Latvia, Energy Division, 2 Perses Street, Riga LV-1442, Latvia

Received 24 January 2008; accepted 8 February 2008

Abstract

This article deals with external cost of electricity generation in Baltic States. The costs of electricity generation and distribution are the most important criteria shaping decisions within the electricity system. However, the external cost due to air pollution should also be adequately taken into account seeking to promote new and clean technologies for electricity generation. External costs of electricity generation in the main power plants burning fossil fuel were calculated based on ExternE methodology for Baltic States during EU Framework 6 project CASES. The article presents the first results of external cost of electricity generation in Baltic States.

Keywords: External cost; Electricity generation

Contents

1. Introduction

The costs of electricity generation and distribution are the most important criteria shaping decisions within the electricity system. However, the influence on the environment and human health due to climate change and air pollution should also be adequately taken into account [1]. This includes impacts from the whole life cycle of electricity supply including operation of a power plant. Thus results from a Life Cycle Inventory (LCI) assessment have to be used [2]. To be able to compare the different impacts of different technologies and systems, the impacts (risks, damage) have to be transformed in a monetary unit. The 'ExternE' methodology is used to weight the, mostly site depended, impacts according to the preferences of the society. As result damage costs, which are mostly external costs are obtained [3].

* Corresponding author. Tel.: +370 37 40 19 58; fax: +370 37 35 12 71.
E-mail address: dalia@mail.lei.lt (D. Streimikiene).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2008.02.004

The sum of the 'private' costs and external costs give social costs. For example, the social costs of an innovative renewable technology may be competitive or even smaller than the social costs of a conventional fossil fuelled technology, even if private costs are higher. The technological progress offers solutions for the challenge of a more sustainable energy supply. The comparison of internal and external cost can help to identify the technologies mix to be aspired.

Therefore, an external cost arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. Thus, a power station that generates emissions of SO_2, NO_x particulates, etc. causing damage to building materials, biodiversity or human health, imposes an external cost. This is because the impact on the owners of the buildings, crops or on those who suffer damage to their health is not taken into account by the generator of the electricity when deciding on the activities causing the damage. Therefore the environmental costs are "external" because, although they are real costs to these members of society, the owner of the power station is not taking them into account when making decisions [4].

During the EU Framework 6 programme under priority Sustainable energy systems CAES project was financed. The aim of the project was to evaluate external and private cost of electricity generation in EU-27 and other countries seeking to provide reliable data for electricity system development scenarios in case then external costs are integrated through all the chain of electricity supply system. During this project external costs of electricity generation for Baltic States were evaluated.

The aim of the article is to compare external costs of electricity generation in Baltic States. The main tasks to achieve this goal are as follows:

- short overview of electricity sectors in Baltic States;
- description of the methodology for external costs of electricity generation calculation;
- evaluation and comparison of external costs of electricity generation in Baltic States.

2. Short overview of electricity sector in Baltic States

2.1. Lithuania

Lithuania inherited from its Soviet past a very powerful energy sector, created with large-scale export possibilities. Almost three-quarters of Lithuania's total electricity production is presently generated by the Ignalina Nuclear Power Plant [5]. An historical summary of electricity generation and consumption structure in Lithuania is shown in Table 1.

The biggest thermal power plant in Lithuania—Lithuanian TPP consists of four 150 MW and four 300 MW units. The oldest units No. 1 and No. 2 operating in combined heat and power production mode had been refurbished before 1990, which extended their lifetime to 2035. The remaining operation resource of other units ranges from 81.9 to 124.4 thousand hours.

The total in stalled capacity of Mazeikiai CHP is 210 MW. This CHP is burning heavy fuel oil (HFO) and serves mainly for the Mazeikiai Oil Refinery needs.

The biggest CHPs are situated in Vilnius and Kaunas. The installed capacity of Vilnius CHP is 384 MW and it can fire both natural gas and heavy fuel oil. The fuel type is chosen depending on the fuel prices. It can easily be converted to orimulsion firing plant as well. Kaunas CHP has installed capacity of 170 MW. The CHP is dual fired (HFO and natural gas) but during the last 5 years was burning just natural gas. There are several smaller CHP in the main cities of Lithuania with total installed capacity of about 120 MW using natural and HFO.

There is Kaunas HPP with total installed capacity of 100 MW. Kaunas Hydro Power Plant has been in operation

Table 1
Electricity production and consumption structure dynamics in Lithuania (GWh) [6]

	1990	1995	2000	2001	2002	2005
Gross electricity production	28,405	13,898	11,425	14,736	17,720	14,784
Ignalina NPP	17,033	11,822	8,419	11,362	14,142	10,338
Public CHP plants	10,809	1,275	2,254	2,589	2,638	3,425
Autoproducers (CHP)	149	50	109	85	160	200
Kruonis HPPS		378	304	375	427	369
Kaunas HPP	396	357	313	284	316	385
Small HPP	18	16	26	41	37	66
Wind						1.8
Net import	−11,975	−2,678	−1,336	−3,964	−6,487	−2,966
Own use in power plants	2,109	1,541	1,385	1,522	1,647	1,201
HPS water pumping	–	517	426	517	580	512
Losses in the network	1,552	2,008	1,281	1,416	1,426	1,220
Other energy sector	756	799	800	871	858	909
Final consumption	14,734	6,371	6,196	6,446	6,722	7,977
Manufacturing	8,274	2,813	2,294	2,346	2,546	2,833
Agriculture	2,942	523	188	197	188	193
Households	1,767	1,499	1,767	1,818	1,811	2,141
Commercial sector	1,504	1,441	1,871	1,995	2,095	2,707
Transportation	248	96	76	90	82	104

since 1960. Some parts of generation and control systems are obsolete and have to be renovated in order to prolong lifetime of the plant and increase reliability of operation. There are about 50 small HPP in Lithuania with total installed capacity of more than 25 MW. There are few windmill parks on sea cost of Lithuania with total installed capacity of 1.1 MW [7].

2.2. Latvia

The dominant role in electricity supply is played by the state company JSC ''Latvenergo'', which provides more than 90% of all electricity generated in Latvia and ensures imports, transmission, distribution and supply to consumers. In addition there are more than 100 small power plants and 10 licensed distribution and sales companies.

The main domestic electricity capacity consists of 1 517 MW of hydro and 520 MW of thermal (CHP units in Riga) all of which is controlled by the state company, Latvenergo. By the nameplate generation capacity of the Latvian power system it seems that there is a surplus of capacity. However, the generating potential mainly consists of three hydro power plants (HPP) on the Daugava River, which means that the amount of generated power is directly dependent on the river's water flow. Due to small reservoirs, utilisation rates are low and the production is quite seasonal following the water flows. The amount of power produced by the Daugava river HPS cascade is average 2.6–2.8 TWh annually, reaching in the years, rich by spring floods and rain (for instance, 1990, 1994 and 1998) even 4.5 TWh. Almost two thirds of hydro electricity is produced in the spring month of March, April and May. In this period practically all of the supplies are from the hydro plants. In the high demand winter season amount of electricity generated by hydro plants is relatively low [8].

Given that all of the thermal capacity is co-generation plants, the electricity production from this source follows the seasonal demand variation to a certain extent being geared to the heat demand, but the major part of the seasonal demand swings are, however, covered with imports. Due to the high share of HPP generation import dependency in electricity supply may exceed 50% (1992, 1996) or be even below 10% (1998). On average, however, import covers around 1/3 of the country's gross domestic consumption (Table 2).

During the past 5 years central (large) power plants in Latvia supplied roughly 65% of the total annual power demand—distributed energy resources (DERs) covered 3–6%, but the rest were received as import supplies from Estonia, Lithuania and Russia.

There are three large hydro power plants (HPPs) in Latvia, which are located on the river of Daugava and form the cascade of the Daugava HPPs—Plavinas HPP 870 MW, Kegums HPP 263 MW and Riga HPP 402 MW.

Two large CHP plants, Riga TPP-1 with an installed electric capacity of 144 MW and Riga TPP-2 (390 MW), are located in the capital of the Latvian republic, the city of Riga. CHP plants are the main heat-generating sources of the right bank heating networks of Riga. Power is produced mainly in cogeneration mode, according to the heat–load curve. Natural gas, peat16 (local resource) and heavy fuel oil (HFO) are used as the main fuels. During the heating season, when there is a substantial demand for heating and hot water, Riga CHP plants produce approximately 80% of the total annual production volume, while during summer the volume of production reduces. Technically, the Riga CHP plants could also operate at full load during the summer (partly in condensing mode), but this is not reasonable from an economic point of view. The maximum power output of plants was in 1991, when 2.3 TWh were generated. In 1992 several industrial consumers (of steam) of the Riga CHP plants went bankrupt as a result of economic recession. Since 1992, the heat load at Riga has decreased for different reasons, such as an efficiency increase of the district heating system and decentralisation. In the past couple of years, heat demand in Riga has started to stabilise and some indications of a possible increase have appeared. Nowadays Riga CHP plants cover about 20% of the total annual power demand of Latvia, generating approximately 1.3 TWh [8].

2.3. Estonia

The Estonian electricity sector is organised around Eesti Energia AS (Estonian Energy Ltd.), which was established as an independent company in 1998 on the basis of the former state enterprise Eesti Energia and its subsidiaries. At present, the Eesti Energia Group incorporates a total of 23 companies, including enterprises that mine oil shale. Eesti Energia AS is a

Table 2
Electricity production and consumption in Latvia (GWh) [8]

	1990	1995	2000	2001	2002	2005
Power supply	10,229	6230	5922	6163	6323	7053
HPP	4,496	2932	2819	2833	2463	3325
CHP	2,147	1042	1313	1444	1501	1533
Wind power plants			4	3	11	47
Import (saldo)	3,586	2256	1786	1883	2348	2148
Losses and own use in plants	2,003	1412	1445	1580	1441	1324
Final consumption	8,226	4818	4477	4583	4882	5729
Manufacturing	3,870	1904	1429	1557	1526	1700
Agriculture	1,720	224	157	150	155	156
Households	1,000	1176	1186	1249	1317	1572
Transportation	430	180	152	174	144	148
Services and other sectors	1,206	1334	1546	1477	1740	2153

100% state-owned vertically integrated public limited company, engaged in power generation, transmission, distribution and sales, as well as in other power-related services throughout almost all of the country. Nevertheless, some privately owned companies deal with generation (small-scale combined heat and power (CHP), mini hydro and wind turbines, and also some industrial CHP plants), as well as with the distribution of electricity. In total, the power plants of Eesti Energia AS generate approximately 98% of the electricity in Estonia. The main generation sources are Estonian and Balti power plants which merged in AS Narva Elektrijaamad in 1999 with total installed capacity of 2700 MW. This power plant uses oil shale. There is also 67 MW of installed capacity power plant—AS Kohtla-Jarve Soojus burning shaile oil as well. The generating capacity based on renewable sources includes only 3.8 MW of hydropower and 2.5 MW of wind turbines [8].

There are a number of small (mini and micro) hydroelectric power plants. The capacity of the largest plant (Linnamäe) is 1.1 MW. The installed capacity of all hydro plants is 3.8 MW and production volume was 20 GWh in 2005. There are some wind turbines, with a total capacity of 2.5 MW and production of 55 GWh (2005). Compared to 2000, the production of hydro energy increased almost three times.

Estonia is a net electricity exporter: in 2005 its net export amounted 1608 GWh. Generated electricity was exported, mainly to Latvia, but also to Russia. Estonia's dependency on imported energy sources is approximately 40% [8].

Electricity consumption and production structure is presented in Table 3.

3. External costs calculation methodology

Seven major types of damages have been assessed within ExternE methodology. The main categories are human health (fatal and non-fatal effects), effects on crops and materials. The impact pathway approach – and coming along with this approach, the EcoSense model, an integrated software tool for environmental impact pathway assessment – was developed within the ExternE project series and represents its core [9].

Impact pathway assessment is a bottom-up-approach in which environmental benefits and costs are estimated by following the pathway from source emissions via quality changes of air, soil and water to physical impacts, before being expressed in monetary benefits and costs. The use of such a detailed bottom-up methodology is necessary, as external costs are highly site-dependent. Two emission scenarios are needed for each calculation, one reference scenario and one case scenario. The background concentration of pollutants in the reference scenario is a significant factor for pollutants with non-linear chemistry or non-linear dose–response functions. The estimated difference in the simulated air quality situation between the case and the reference situation is combined with exposure response functions to derive differences in physical impacts on public health, crops and building material [10].

It is important to note, that not only local damages have to be considered—air pollutants are transformed and transported and cause considerable damage hundreds of kilometres away form the source. So local and European wide modelling was performed during ExternE and its extensions [9]. As a next step within the pathway approach, exposure response models are used to derive physical impacts on the basis of these receptor data and concentration levels of air pollutants. In the last step of the pathway approach, the physical impacts are evaluated in monetary terms. According to welfare theory, damages represent welfare losses for individuals. For some of the impacts (crops and materials), market prices can be used to evaluate the damages. However, for non-market goods (especially damages to human health), evaluation is only possible on the basis of the willingness-to-pay or willingness-to-accept approach that is based on individual preferences. To complete the external costs accounting framework for environmental themes (acidification and eutrophication, a complementary approach for the valuation of such impacts based on the standard-price approach is developed and

Table 3
Electricity production and consumption structure dynamics in Estonia (GWh) [8]

	1990	1995	2000	2001	2002	2005
Production	17,181	9152	8268	8483	8527	10205
Import–export	−7,032	−1191	−596	−929	−622	−1608
Own use in plants	1,733	1146	916	922	893	1091
Losses	1,147	1527	1470	1240	1361	1543
Final consumption	7,299	5288	5286	5422	5607	5963
Manufacturing	3,534	2209	2206	2259	2263	2091
Agriculture	2,006	434	247	224	204	222
Households	881	1270	1363	1466	1585	1620
Transportation	174	194	94	93	84	103
Other sectors	704	1181	1376	1380	1471	1927

Table 4
External costs of the classical pollutants releases in Baltic States (Eur/t)

	ES-27	Lithuania	Latvia	Estonia
Human health impact				
NH_3	9,482	4,348	4825	5103
NMVOC	584	326	296	163
NO_x	5,591	3,966	2590	1481
PPM_{25}	1,325	390	342	165
PPM_{coars}	24,410	10,969	8844	6159
SO_2	6,070	4,412	3854	3392
Biodiversity losses				
NH_3	3,266	2,229	2980	3188
NMVOC	−67	−28	−34	−29
NO_x	903	590	638	676
SO_2	177	139	133	167
Impact on crops				
NH_3	−183	−11	−8	−7
NMVOC	189	35	40	30
NO_x	328	129	119	84
SO_2	−27	−14	−11	−11
Impact on materials				
NO_x	71	74	47	31
SO_2	259	187	125	95

Table 5
Emissions of classical pollutants from Lithuanian electricity generation sources in 2005 (thou. t)

Power plants	SO_2	NO_x	NH_3	NMVOC	PPM_{25}	PPM_{coars}
Lithuanian TPP	3.26	0.96	0.0	0.00002	0.00008	0.002
Vilnius CHP	0.15	0.63	0.0	0.01	0.003	0.00006
Mazeikiai TE	3.67	0.23	0.000001	0.02	0.09	0.01
Kauno TE.	0.0004	0.02	0.0	0.0	0.003	0.0
Ignalina NPP	0.0-	0.01	0.0	0.004	0.005	0.00001
Total emissions in electricity generation (thout. t)	8.9	3.6	0.0001	0.08	0.28	0.02

improved. This procedure deviates from the pure welfare economic paradigm followed in ExternE, but it allows to estimate damage figures for ecological impacts complementary to the existing data on impacts from the same pollutants on public health, materials and crops (based on damage function approach and welfare based valuation studies). The integration of this methodology and data into the existing external costs framework is an important extension as it also covers impact categories that could otherwise not be addressed properly in ExternE. To perform the calculations, a software package called EcoSense is used. EcoSense provides harmonised air quality and impact assessment models together with a database containing the relevant input data for the whole of Europe. In general, dependent on the question to be answered, the analysis is not only made for the operation of the technology to be assessed as such, but also including other stages of the life cycle (e.g. construction, dismantling, transport of materials and fuels, fuel life cycle).

4. External costs of electricity generation in Baltic States

Within framework of CASES project based on EcoSence model run the external cost for classical air pollutants corresponding to an average height of release were obtained for 39 European and non-European countries and five sea regions, and for the EU-27 as an average. The values are based on parameterised results of a complex dispersion model. The meteorological values reflect an average of the results for different meteorological years, namely 1996, 1997, 1998 and 2000. This has been performed in order to reflect not only one, more or less arbitrary year, but more typical and average conditions.

Results are available for emission of: NH_3, NMVOC, NO_x; PPM_{coars}—PPM_{25} and SO_2. The receptor domain covers the whole of Europe regarding impacts to human health, crops, damage to materials ‘‘Loss of Biodiversity’’ caused by

Table 6
External cost of electricity generation in Lithuania in 2005 (thou. Eur)

	Lithuanian PP	Vilnius CHP	Mažeikiai CHP	Kaunas CHP	Ignalina NNP	Total external cost in electricity sector
Human health						
NH_3	0.0	0.0	0.005	0.0	0.0	0.4
NMVOC	0.0	0.0	0.0	0.0	0.0	26.1
NO_x	3795.5	2494.6	920.1	1.6	47.6	14392.6
PPM_{25}	0.0	1.2	34.0	1.3	1.9	0.0
PPM_{coars}	16.5	0.7	156.9	0.0	0.2	252.3
SO_2	14400.8	639.7	16192.0	1.8	0.0	39416.8
Biodiversity losses						
NH_3	0.0	0.0	0.0	0.0	0.0	0.2
NMVOC	0.0	0.0	0.0	0.0	0.0	0.0
NO_x	564.6	371.1	136.9	8.9	7.1	2141.1
SO_2	453.7	20.2	510.1	0.2	0.0	1241.8
Impact on crops						
NH_3	0.0	0.0	0.0	0.0	0.0	0.0
NMVOC	0.0	0.5	0.6	0.0	0.1	2.8
NO_x	123.5	81.1	29.9	1.9	1.5	468.1
SO_2	−45.7	−2.0	−51.4	0.0	0.0	−125.1
Impact on materials						
NO_x	70.8	46.5	17.2	1.1	0.9	268.5
SO_2	610.4	27.1	686.3	0.1	0.0	1670.7
Total external cost in electricity sector (thou. EUR)	19990	3680.7	18632.6	16.8	59.3	59756.5
El. production (GWh)	1073.0	1164	160.0	695.0	10338.0	14784.0
External cost (EUR/kWh)	0.02	0.003	0.12	0.00002	0.00001	0.004
External cost (Ltcnt/kWh)	6.45	1.04	40.44	0.01	0.002	1.40

Table 7
Emissions of classical pollutants from the main Latvian power plants in 2005 (t)

	Thermal power plant -1	Thermal power plant-2	Latvian HPP	Total from these PP
SO_2	0.03	0.0	20212.0	20212.0
NO_x	335.0	1627.3	1844.0	3806.3
NMVOC	0.0	3.0	0.0	3.0
PPM_{25}	0.004	0.0	0.52	0.52
SO_2	0.0	0.0	0.08	0.08

acidification and eutrophication, newly implemented into the assessment framework of EcoSence. In Table 4 the external cost of classical pollutants releases for EU-27, Lithuania, Latvia, Estonia are presented.

4.1. Lithuania

Based on information provided in Table 4 we will calculate external cost of electricity generation in Lithuania based on emission into atmosphere of classical pollutants from the main electricity generation sources provided in Table 5.

In the last row of Table 5 the total emissions of classical pollutants from electricity sector of Lithuania are presented. Lithuanian external costs of electricity generation are presented in Table 6.

As one can see from Table 6 the average cost of electricity generation in Lithuania estimated per kWh in 2005 amounted to 1.4 Ltct/kWh or 0.4 Eurcnt/kWh. The highest external cost in Lithuania were at Mazeikiai CHP, which is burning HFO. The lowest external costs were at Kaunas CHP which was burning mainly natural gas in 2005. The low cost were in Vilnius CHP which is also using mainly natural gas.

4.2. Latvia

Based on information provided in Table 4 and emission data provided in Table 7 the external costs of electricity generation in Latvia were calculated.

Latvian external costs of electricity production at the main power plants are presented in Table 8.

As one can see from Table 8 average external cost of electricity generation in Latvia makes about 7 Ltct/kWh or 2 Eurcnt/kWh. The highest external cost of electricity generation is in Latvian HPP because this large hydropower cascade has two thermal units of 1.85 MW burning high sulphur HFO. Ryga CHP-1 has the lowest external electricity generation cost because is burning just natural gas. Ryga CHP-2 also uses gas and diesel oil.

4.3. Estonia

Based on information provided in Table 4 and emission data provided in Table 9 the external costs of electricity generation in Estonia were calculated.

External costs of electricity generation in the main power plants are provided in Table 10.

Table 8
External cost of electricity generation in Latvia in 2005 (thou. Eur)

	Thermal power plant -1	Latvian HPP	Thermal power plant-2	Total
Human health				
NMVOC	0.0	0.0	891.0	891.0
NO_x	867650.0	4775960.0	4214745.9	9858355.9
PPM_{25}	1.4	176.5	0.0	177.8
PPM_{coars}	0.0	725.2	0.0	725.2
SO_2	96.4	77897048.0	0.0	77897144.4
Biodiversity losses				
NH_3	0.0	0.0	0.0	0.0
NMVOC	0.0	0.0	−102.3	−102.3
NO_x	213730.0	1176472.0	1038227.0	2428429.0
SO_2	3.3	2688196.0	0.0	2688199.3
Impact on crops				
NMVOC	0.0	0.0	120.4	120.4
NO_x	39865.0	219436.0	193650.5	452951.5
SO_2	−0.28	−222332.0	0.0	−222332.3
Impact on materials				
NO_x	15745.0	86668.0	76483.8	178896.8
SO_2	3.125	2526500.0	0.0	2526503.13
Total external cost in electricity sector (thou. EUR)	1137.1	89148.9	5524.0	95810.0
El. production (GWh)	391.0	3325.0	1142.0	4905.0
External cost (EUR/kWh)	0.003	0.03	0.01	0.02
External cost (Ltcnt/kWh)	1.01	9.31	1.68	6.78

Table 9
Emissions of classical pollutants from the main Estonian power plants in 2005 (thou. t)

	Eesti power plant	Balti power plant	Kohtla Järve PP	Ahtme power plant	Iru Power plant	Total from these PP
SO_2	46.3	8.2	2.04	1.95	0.0	58.49
NO_x	7.2	1.6	0.08	0.23	1.04	10.15
NMVOC	0.0	0.0	0.04	0.0	0.02	0.06
PPM_{25}	3.5	5.2	0.03	1.21	0.0	9.94

Table 10
External cost of electricity generation in Estonia in 2005 (thou. Eur)

	Eesti power plant	Balti power plant	Kohtla Järve PP	Ahtme power plant	Iru power plant	Total
Human health						
NMVOC	0.0	0.0	6.5	0.0	3.3	9.8
NO_x	10663.2	2369.6	118.5	340.6	1540.2	15032.2
PPM_{25}	577.5	858.0	5.0	199.7	0.0	1640.1
SO_2	157049.6	27814.4	6919.7	6614.4	0.0	198398.1
Biodiversity losses						
NH_3	0.0	0.0	0.0	0.0	0.0	0.0
NMVOC	0.0	0.0	−1.2	0.0	−0.6	−1.7
NO_x	4867.2	1081.6	54.1	155.5	703.0	6861.4
SO_2	7732.1	1369.4	340.7	325.7	0.0	9767.8
Impact on crops						
NH_3	0.0	0.0	0.0	0.0	0.0	0.0
NMVOC	0.0	0.0	1.2	0.0	0.6	1.8
NO_x	604.8	134.4	6.7	19.3	87.4	852.6
SO_2	−509.3	−90.2	−22.4	−21.5	0.0	−643.4
Impact on materials						
NO_x	223.2	49.6	2.5	7.1	32.2	314.7
SO_2	4398.5	779.0	193.8	185.3	0.0	5556.6
Total external cost in electricity sector (thou. EUR)	185606.8	34365.8	7625.0	7826.1	2366.2	237789.8
El. production (GWh)	6726.1	1672.9	1773.7	32.4	398.9	10205.0
External cost (EUR/kWh)	0.03	0.02	0.24	0.24	0.01	0.02
External cost (Ltcnt/kWh)	9.5	7.1	81.9	84.0	2.1	8.1

As on can see from Table 10 the average external cost of electricity generation in Estonia is 8.1 Ltct/kWh or 2.3 Eurcnt/kWh. The highest external cost in Estonian electricity sector is at Kohtla Järve PP and Ahtme Power Plant, both burning shale oil. The lowest external cost is at Iru PP which is burning natural gas. The external electricity generation cost at bith Narva PP are similar to average external cost of electricity system as these power plants produce more than 80% of total electricity generated in Estonia and makes about 3 Eurcnt/kWh.

5. Conclusions

1. The costs of electricity generation and distribution are the most important criteria shaping decisions within the electricity system. However, the influence on the environment and human health due to air pollution should also be adequately taken into account seeking to promote new and clean technologies for electricity generation.
2. External costs of electricity generation in the main power plants burning fossil fuel were calculated based on ExternE methodology for Baltic States during EU Framework 6 project CASES which aims to calculate external and private cost of electricity generation in EU-27 and other countries.
3. Comparing external cost of electricity generation in Baltic States one can notice that the highest external cost are in Estonia as Estonian power sector is mainly based on local fuel—oil shale which has a high sulphur content. The lowest external cost of electricity generation are in Lithuania as more than 80% of electricity is generated at Ignalina NPP which has very low external cost—0.01 Eurcnt/kWh. External cost of electricity generation in Latvia are higher than in Lithuania mainly because Latvian HPP cascade has thermal units burning high-sulphur HFO.

Acknowledgement

This article has been produced with the financial assistance of the European Commission FM 6 project under thematic priority: Sustainable energy Systems CASES (Cost Assessment of Sustainable Energy Systems) http://www.feem-project.nt/cases/) but views expressed herein are those of authors and can therefore in no way be taken to reflect the official opinion of the

European Commission. The project will run until September 2008.

References

[1] Hohmeyer O. Social costs of energy consumption. Berlin: Springer Verlag; 1988.
[2] Frischknecht R. Ecoinvent database methodology. In: Presentation for Special LCA forum; 2003.
[3] Commission of the European Communities Joule Programme. ExternE: externalities of energy, 1995.
[4] European Commission. ExternE—Externalities of Energy, vol. 7. Methodology 1998 Update. Luxemburg: Office for Official Publications of the European Communities, 1999, pp. 9–15.
[5] Štreimikienė D. Implementation of EU environmental directives and Kyoto protocol requirements in Lithuanian power and district heating sectors. Power Eng 2004;3:30–9.
[6] Lithuanian Energy Institute. Energy in Lithuania 2006, Kaunas, 2007.
[7] Lithuanian Ministry of Economy. National Energy Strategy. Vilnius, 2007.
[8] Analysis of energy supply options and security of energy supply in the Baltic States, IAEA: Vienna, 2006.
[9] European Commission. Work Package 6: Revision of external cost estimates. In: New elements for the assessment of external costs from energy technologies (NewExt). Final Report. Contract No. ENGI-CT2000-00129. 2004.
[10] Schlesinner L, Nielsen PS. External costs related to power production technologies ExternE national implementation for Denmark. Copenhagen: Risø National Laboratory; 1997. pp. 2–13.

Dalia Streimikiene is a senior researcher at Lithuanian Energy Institute. She graduated from Kaunas Technological University in 1985 and obtained PhD in Vilnius Technical University in 1997 and passed habilitation procedures in 2005 in the same university. The main areas of research are energy and environmental economics and policy, development of economic tools for environmental regulation in energy sector, promotion of renewable energy sources and sustainable energy development. She authored more than 70 scientific publications in foreign and Lithuanian scientific journals.

Inge Roos is a researcher at Tallinn University of Technology. She has wide experience in climate change mitigation policies development in Estonian energy sector. She was also involved in several projects dealing with environmental issues of Estonian energy sector and has experience in external costs of electricity generation in Estonia.

Janis Rekis has PhD in Technical Science at Tallinn University of Technology. He has wide experience in energy sector of Latvia and was involved in numerous projects dealing with energy and environmental planning of electricity sector in Latvia, climate change mitigation policies in energy sector.